Bull. nat. Hist. Mus. Lond. (Geol.) **58**(1): 1–11 Issued 27 June 2002

Gough's Cave 1 (Somerset, England): a study of the axial skeleton

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SYNOPSIS. The postcranial axial skeleton of Cheddar Man (Gough's Cave 1) is represented by seventeen presacral vertebrae, the sacrum, and nineteen ribs, all of which are relatively well-preserved. Cheddar Man derives from early Holocene deposits in Gough's Cave, and the remains of his axial postcranial skeleton are described here. Comparative evaluation of the Gough's Cave 1 remains reveals an axial skeleton that falls within the range of variation in size and shape of males of the same time period, albeit towards the small end of that range (reflecting relatively short stature in Cheddar Man).

INTRODUCTION

The postcranial axial skeleton of Cheddar Man is represented by a single cervical vertebra, eleven thoracic vertebrae, all five lumbar vertebrae, sacrum, and nineteen ribs. The hyoid, manubrium, sternum and xiphoid process were not recovered. The preservation of the recovered vertebrae is generally good, with many being complete. Sequencing of vertebrae was based on size, details of morphology of the articular facets, neural arches, and transverse and spinous processes, and by evaluating the articulation of each element with the identified supra- and subjacent vertebrae (Bass, 1987; Steele & Bramblett, 1988). Prior efforts to reconstruct the entire articulated vertebral column for museum display involved the gluing of fibrous pads (to represent the intervertebral discs) to the bodies of many of the vertebrae, and in some cases elements were glued to 'mocked up' replicas of the missing vertebrae, making observation and measurement of morphology difficult (only the fifth and eighth thoracic and the third lumbar vertebrae could be entirely separated from reconstructive materials: these specimens were thus singled out for photography). The ribs are also in a very good state of preservation overall; more than half of them preserve the head, neck and tubercles proximally and most are complete distally to the area around the anterior angle. Sequencing of ribs was accomplished by examining overall size and shape, the position of the *M. iliocostalis* line, size and shape of the articular facets, and the height of the rib heads (with the inferior bodies held in the same plane) relative to one another (Mann, 1993). A number of the ribs bear cut marks that may be attributable to stone tools.

Each vertebra is briefly described, followed by a discussion of the vertebral morphology of Gough's Cave 1 (the sacrum is described along with the os coxae in Trinkaus, this series). The ribs are then likewise described and their morphology discussed.

MATERIALS AND METHODS

The description of the Gough's Cave 1 axial postcranial remains is augmented by osteometric data and comparisons with various samples of fossil and recent humans. The necessity of accurate identification of vertebral and costal number (i.e., the position of the element in the series) for collection of comparative data presents difficulties in working with fragmentary fossil material (see Franciscus & Churchill, 2002). For vertebral morphology, comparative osteometrics were collected on European terminal Pleistocene specimens (all associated with Late Upper Paleolithic assemblages, and dating between 19,000 and 11,000 ybp) and early Holocene specimens (associated with Mesolithic assemblages and dating between 10,000 and 5,000 ybp). These two samples thus bracket in age the Gough's Cave 1 skeleton. The terminal Pleistocene sample includes Arene Candide 2, 4, 5, 10 and 12, Bichon 1, Bruniquel 24, Cap Blanc 1, Chancelade 1, Grotta Contineza, Grotte des Enfants 3, La Madeleine, Oberkassel 1 and 2, Parabita 1 and 2, Le Peyrat 5 and 6, Romito 4, St. Germain La Rivière 4 and Veyrier 1 (Paoli *et al.*, 1980; Simon & Morel, nd; Genet-Varcin & Miquel, 1967; von Bonin, 1935; Vallois, 1941–46, 1972; Verneau, 1906; de Quatrefages & Hamy, 1882; Verworn *et al.*, 1919; Cremonesi *et al.*, 1972; Patte, 1968; Graziosi, 1962; Vallois, 1972; Pittard & Sauter, 1945). The early Holocene sample is composed of Los Azules, Gramat 1, Hoëdic 8 and 9, Rastel 1, Téviec 1, 11 and 16 (Fernández-Tresguerres, 1976; Lacam *et al.*, 1944; Barral & Primard, 1962; Péquart *et al.*, 1937). Additional comparative data was collected on recent Europeans (n = 125), north Africans (n = 61) and sub-Saharan Africans (n = 26) (details of sample composition are provided in Holliday, 1995). For the ribs, comparative data is limited to a small sample of recent European-Americans (n = 20: Franciscus & Churchill, 2002).

Operational definitions of the measurements employed can be found in Martin (1928) or as footnotes to Tables. Vertebral osteometrics are provided in Tables 1–3, costal osteometrics are in Tables 6–8. All measurements were taken by the authors on the original specimens; measurements quoted in brackets in Tables 1–9 are estimated values.

VERTEBRAL REMAINS

Descriptions

CERVICAL VERTEBRA 6 OR 7 (FIG. 1)

A single cervical vertebra, complete except for some damage to the left side ventral surface of the corpus, is preserved (at bottom of Fig. 1). Based on its size and neural arch morphology (the transverse processes are large and laterally flaring) it appears to be either the 6th or 7th cervical vertebra (this element is attached superiorly to a 'mocked up' cervical vertebral column, thus preventing examination

Fig. 1 Gough's Cave 1 sixth or seventh cervical vertebra at bottom of figure, articulated to four reconstructed vertebra above; lateral view; × 1.

Table 1 Dimensions (mm) of the sixth cervical vertebra.

Dorso-ventral diameter[1]	56.8
Superior external transverse articular diameter[2]	51.7
Superior internal transverse articular diameter[3]	(31.5)
Superior transverse articular diameter[4]	41.6
Inferior external transverse articular diameter[5]	48.3
Inferior internal transverse articular diameter[6]	21.8
Inferior transverse articular diameter[7]	35.1
Spinal canal dorso-ventral diameter (M-10)	14.7
Spinal canal transverse diameter (M-11)	21.5
Spinous process length[8]	29.2
Spinous process angle[9]	5°
Body ventral height (M-1)	(12.2)
Body inferior dorso-ventral diameter (M-5)	17.3
Body inferior transverse diameter (M-8)	28.6

[1]From the mid-ventral surface of the body to the dorsal tip of the spinous process.
[2]Maximum distance between the lateral edges of the superior articular facets.
[3]Maximum distance between the medial edges of the superior articular facets.
[4]Average of the external and internal transverse articular diameters of the superior articular facets.
[5]Maximum distance between the lateral edges of the inferior articular facets.
[6] Maximum distance between the medial edges of the inferior articular facets.
[7]Average of the external and internal transverse articular diameters of the inferior articular facets.
[8]From the ventro-superior margin of the intersection of the laminae and the spinous process to the dorsal tip of the spinous process (not including the unfused tubercle).
[9]The angle between the central long axis of the spinous process and the horizontal plane of the superior surface of the body, taken in the median sagittal plane of the vertebra.

of the superior surface of the corpus and making its identification more difficult). The first thoracic vertebra is preserved, and it articulates poorly with this element, suggesting that this is the 6th cervical vertebra. The inferior surface of the body is concave (not flat as is normally found in 7th cervical vertebra: Bass, 1987), and the anterior tubercle of the transverse process is relatively large and thus looks to be the carotid tubercle of C6. In addition, the end of the spinous

Table 2 Dimensions (mm) of the thoracic vertebrae.

	T1	T2/3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Dorso-ventral Diameter[1]	60.2	–	–	–	68.5[11]	69.0[11]	–	–	71.1[11]	67.8[11]	(69.2)[11]
Superior external transverse articular diameter[2]	46.1	–	36.2	–	31.4	32.9	33.1	34.3	35.9	38.3	–
Superior internal transverse articular diameter[3]	21.9	–	15.5	15.2	13.7	–	15.2	14.7	12.5	15.1	–
Superior transverse articular diameter[4]	34.0	–	25.9	–	22.6	–	24.2	24.5	24.2	26.7	–
Inferior external transverse articular diameter[5]	–	38.0	37.1	33.9	34.4	34.5	–	37.5	38.7	–	36.2
Inferior internal transverse articular diameter[6]	–	14.8	13.8	12.9	–	13.6	–	–	10.4	–	17.3
Inferior transverse articular diameter[7]	–	26.4	25.5	23.4	–	24.1	–	–	24.6	–	26.8
Spinal canal dorso-ventral diameter (M-10)	16.7	–	16.5	17.1	15.2	–	17.8	16.8	–	17.3	–
Spinal canal transverse diameter (M-11)	20.9	(18.4)	16.5	17.1	17.4	17.1	17.3	18.2	17.7	20.0	20.3
Spinous process length[8]	31.3[11]	(30)[11]	–	–	36.4[11]	37.8[11]	–	–	36.3[11]	29.1[11]	26.3
Spinous process angle[9]	8°	–	–	–	47°	70°	–	–	55°	45°	16°
Body ventral height (M-1)	13.7	–	17.3	18.0	17.0	18.3	19.4	18.8	19.1	19.4	(20)
Body dorsal height (M-2)	–	–	17.4	18.1	–	–	20.1	–	–	–	–
Body median height (M-3)	–	–	–	15.8	–	–	19.4	–	–	–	–
Body superior dorso-ventral diameter (M-4)	18.4	–	22.0	23.2	25.7	–	28.9	32.8	30.7	32.2	–
Body superior transverse diameter (M-7)[10]	30.2	–	26.7	26.9	29.7	31.1	32.2	36.2	36.5	39.4	–
Body inferior dorso-ventral diameter (M-5)	–	–	21.7	25.6	–	30.2	32.5	–	32.4	–	(34)
Body inferior transverse diameter (M-6)[10]	–	–	28.5	28.7	31.3	32.8	36.4	38.2	39.3	42.3	41.7

[1]From the mid-ventral surface of the body to the dorsal tip of the spinous process.
[2]Maximum distance between the lateral edges of the superior articular facets.
[3]Maximum distance between the medial edges of the superior articular facets.
[4]Average of the external and internal transverse articular diameters of the superior articular facets.
[5]Maximum distance between the lateral edges of the inferior articular facets.
[6]Maximum distance between the medial edges of the inferior articular facets.
[7]Average of the external and internal transverse articular diameters of the inferior articular facets.
[8]From the ventro-superior margin of the intersection of the laminae and the spinous process to the dorsal tip of the spinous process (not including the unfused tubercle).
[9]The angle between the central long axis of the spinous process and the horizontal plane of the superior surface of the body, taken in the median sagittal plane of the vertebra.
[10]Transverse body dimensions did not include the articular facets for the rib head.
[11]Dorsal tubercle of spinous process unfused and missing.

process looks as though it gave rise to a bifid tubercle (the spinous process of the seventh cervical vertebra generally ends in a single tubercle (Williams & Warwick, 1980)), although the secondary centre of ossification is unfused and the process is preserved as a single tubercle. These features suggest that this bone represents the sixth cervical vertebra.

The spinous process projects nearly horizontally from the body (Table 1), as is common in lower cervical vertebrae. The corpus is wide in the transverse dimension relative to its dorso-ventral diameter. As in all lower cervical vertebrae, the spinal canal is wider transversely than dorso-ventrally, and is triangular in outline.

THORACIC VERTEBRA 1 (FIG. 2)

The first thoracic vertebra is largely complete. The right side transverse process is broken off and the left side process is missing a small portion of its lateral end. The posterior tubercle of the spinous process is unfused. A crack runs through the left side neural arch lamina and inferior and superior articular facets. The vertebra cannot be viewed from the inferior perspective due to adherent reconstructive materials.

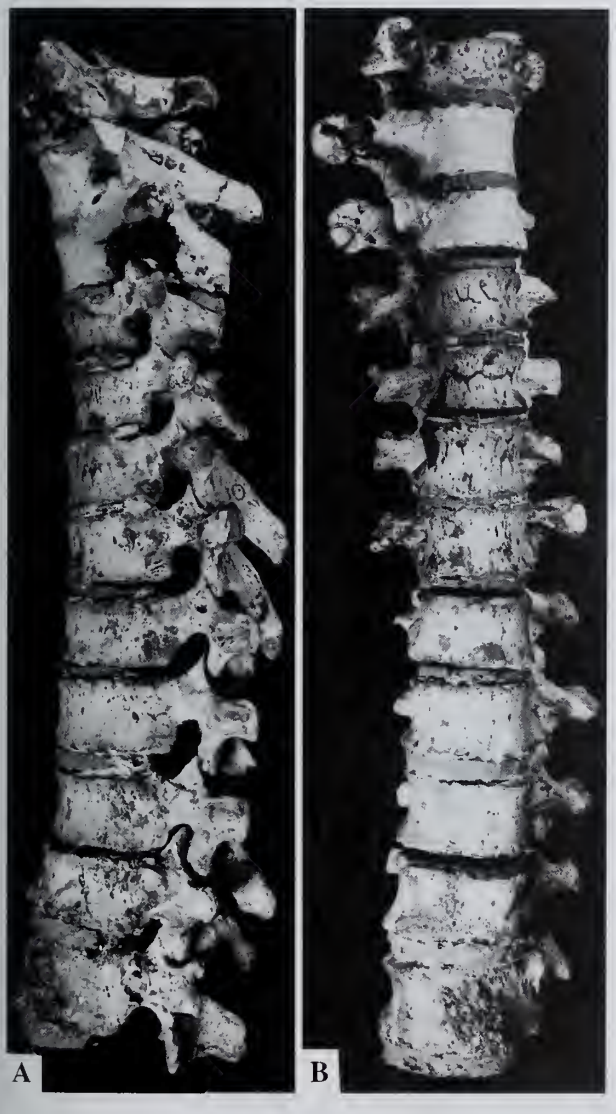

Fig. 2 Gough's Cave 1 thoracic vertebrae 1–12 in articulation. **2a,** lateral; **2b,** ventral; × 0.48. Note that reconstructed intervertebral disks of uniform thickness dorso-ventrally have been inserted between some of the vertebral bodies, probably diminishing the degree of curvature that would have obtained during life.

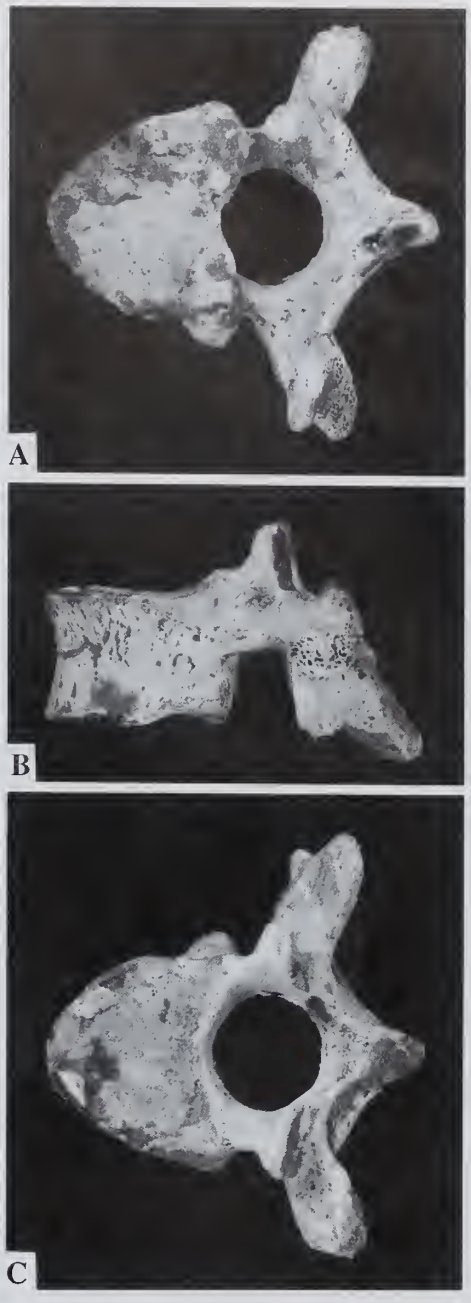

Fig. 3 Gough's Cave 1 fifth thoracic vertebra. **3a,** superior; **3b,** lateral; **3c,** inferior; × 1.

The spinous process projects nearly horizontally from the corpus (Table 2). The dorso-ventral diameter of the spinal canal is somewhat smaller than the transverse diameter.

THORACIC VERTEBRA 2 OR 3

The second or third thoracic vertebra is represented by the posterior portion of a neural arch only. This fragment includes the left side

lamina with the inferior articular facet, spinous process (with the posterior tubercle missing), and the right side lamina with the transverse process and superior and inferior articular facets.

THORACIC VERTEBRA 4

This vertebra is complete except for the posterior half of the spinous process and the left side transverse process (Fig. 2). The superior and inferior surfaces of the body are obscured by reconstructive materials.

The dorsal and ventral supero-inferior heights of the body are equal in this vertebra (Table 2). As with all of the thoracic vertebrae, the corpus has a greater transverse than dorso-ventral diameter (although the difference is not as great as that seen in the preserved [sixth or seventh] cervical vertebra). The dimensions of the spinal canal are equal in the transverse and dorso-ventral directions.

THORACIC VERTEBRA 5 (FIGS 2, 3)

The fifth thoracic vertebra is complete except for most of the spinous process, the dorsolateral surface of the right transverse process, and the lateral end of the left transverse process (Fig. 3)

As with the fourth thoracic vertebra, the dorsal and ventral supero-inferior heights of the body are equal (Table 2). The dimensions of the spinal canal are equal in the transverse and dorso-ventral directions.

THORACIC VERTEBRA 6

This vertebra is complete except for the lateral ends of both transverse processes (Fig. 2). This specimen is attached to the seventh thoracic vertebra inferiorly, and has reconstructive materials adherent to the superior surface of the body.

The spinous process is infero-dorsally oriented (Table 2). The transverse diameter of the spinal canal is slightly greater than the dorso-ventral diameter in this element.

THORACIC VERTEBRA 7

This element is complete except for the very tip of the spinous process and the lateral end of the right transverse process. This vertebra is affixed to the sixth thoracic vertebra superiorly and the inferior surface of the corpus is obscured by reconstructive material.

The spinous process is strongly angled inferiorly (Table 2), and the transverse and dorso-ventral diameters of the body are sub-equal (with the transverse dimension being slightly larger).

THORACIC VERTEBRA 8 (FIGS 2, 4)

This vertebra is mostly complete, lacking only the left side inferior costal facet (on the body), the right transverse process, the left inferior articular facet, and most of the spinous process (Fig. 4). The neural arch is cracked in several places and reconstructed.

The dorsal supero-inferior height of the corpus is slightly greater than that of the ventral body (Table 2). The transverse and sagittal dimensions of the spinal canal are roughly equal in this vertebra.

THORACIC VERTEBRA 9

The ninth thoracic vertebra is complete except for the end of the spinous process. The neural arch is broken off through both pedicles and has been reconstructed. This vertebra is attached to the tenth thoracic vertebra inferiorly and the superior surface of the corpus is covered by reconstructive material.

The spinal canal of this vertebra shows an expansion of the transverse diameter and a diminution of the dorso-ventral diameter of the spinal canal relative to that of the suprajacent vertebra (Table 2).

THORACIC VERTEBRA 10

This vertebra is complete, but displays some slight damage to the right side inferolateral edge of the body. This specimen is attached to the ninth thoracic vertebra superiorly.

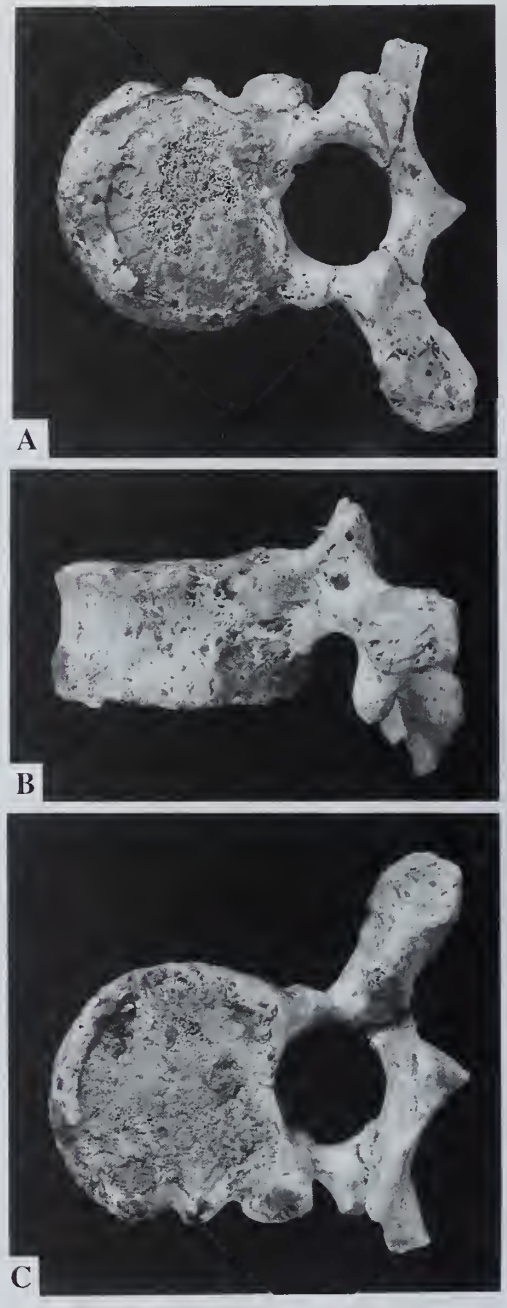

Fig. 4 Gough's Cave 1 eighth thoracic vertebra. **4a,** superior; **4b,** lateral; **4c,** inferior; × 1.

The spinous process is infero-dorsally directed, and is not as sharply inferiorly angled as that of the seventh thoracic vertebra (Table 2).

THORACIC VERTEBRA 11

The eleventh thoracic vertebra is complete except for the very tip of the spinous process. The vertebra has some slight erosion to the inferior left side of the ventral surface of the corpus. The tip of the spinous process appears to be unfused. It is affixed to the twelfth thoracic vertebra inferiorly.

The specimen exhibits slight anterior wedging of its body. The

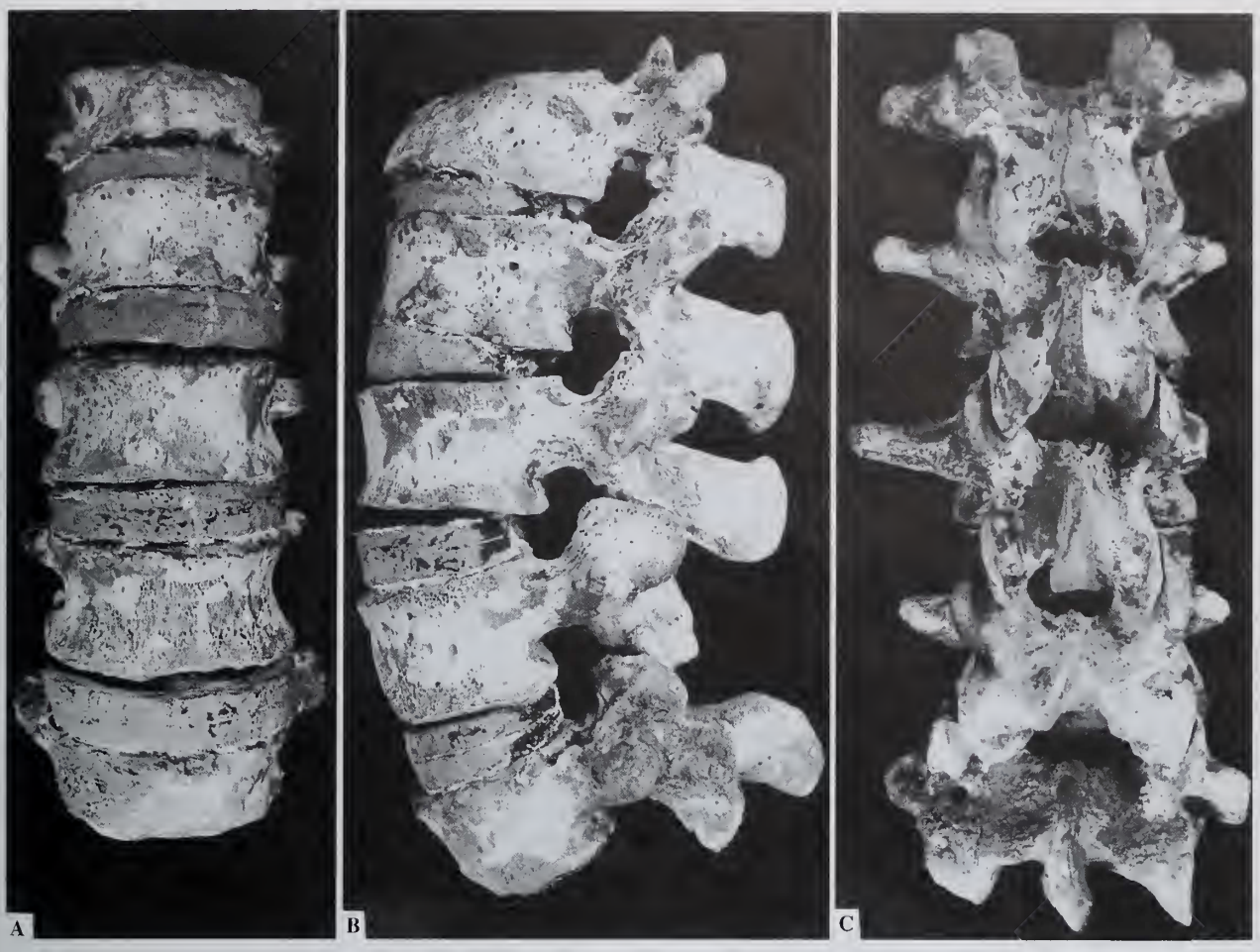

Fig. 5 Gough's Cave 1 lumbar vertebrae in articulation. **5a,** ventral; **5b,** lateral; **5c,** dorsal; × 0.72. Reconstructed intervertebral disks have been inserted between the lumbar bodies.

spinous process has a more moderate inferior projection than that of the suprajacent vertebra (Table 2), and the spinal canal has a greater transverse than dorso-ventral diameter.

THORACIC VERTEBRA 12

The twelfth thoracic vertebra is largely complete. This bone lacks only a portion of the left side ventral and lateral surfaces of the body, and the dorsolateral tip of the transverse process. The tip of the spinous process is unfused and missing, and the annular ring of the inferior surface is not fully fused to the centrum. The specimen is attached to the eleventh thoracic vertebra superiorly and its inferior surface is obscured by reconstructive material.

The spinous process forms a moderate (inferiorly directed) angle with the plane of the body (Table 2). As with the lumbar vertebrae, the transverse diameter of the body is considerably greater than the dorso-ventral dimension.

LUMBAR VERTEBRA 1 (FIG. 5)

The first lumbar vertebra is largely complete, lacking only the right side mammillary process. Some erosional damage is evident on the ventral surface of the body. The posterior tip of the spinous process appears to be unfused and missing (this region is obscured by reconstructive materials making observation of the morphology difficult). The bone is cracked through the right side pedicle and lamina and has been reconstructed. The specimen is attached inferiorly to the second lumbar vertebra.

The body of the first lumbar vertebra exhibits marked anterior wedging (a much greater dorsoventral dimension inferiorly than superiorly: Table 3; Fig. 5). Erosion and damage to the anterior surface precludes measurement of the inferior dorsoventral diameter, and may accentuate the degree of wedging evident in the specimen. The spinous process is short and projects horizontally from the body (Table 3). The spinal canal transverse diameter is the largest of all the lumbar vertebrae, and is considerably greater than the dorso-ventral diameter.

LUMBAR VERTEBRA 2

This specimen is complete except for the lateral part of the right side transverse process (Fig. 5). The secondary centre of ossification for the tubercle of the spinous process is fused but the epiphyseal line is still open along its superior margin. The epiphyseal line between the secondary centre of ossification of the inferior annular ring and the centrum is also evident (but is mostly closed and was undergoing obliteration at the time of death). This bone is attached to the first lumbar vertebra superiorly and its inferior surface is covered by reconstructive material.

Table 3 Dimensions (mm) of the lumbar vertebrae.

	L1	L2	L3	L4	L5
Dorso-ventral Diameter[1]	80.2[11]	85.1	86.4	–	79.3
Superior external transverse articular diameter[2]	35.7	30.3	34.8	37.8	54.7
Superior internal transverse articular diameter[3]	17.4	–	20.9	20.3	21.3
Superior transverse articular diameter[4]	26.6	–	27.9	29.1	38.0
Inferior external transverse articular diameter[5]	29.6	31.0	34.1	46.2	52.4
Inferior internal transverse articular diameter[6]	–	18.8	16.4	19.8	27.9
Inferior transverse articular diameter[7]	–	24.9	25.3	33.0	40.2
Spinal canal dorso-ventral diameter (M-10)	18.9	–	15.2	17.0	18.3
Spinal canal transverse diameter (M-11)	24.2	20.9	21.8	22.6	22.9
Spinous process length[8]	27.8[11]	33.9	37.5	–	34.6
Spinous process angle[9]	2°	2°	16°	–	30°
Body ventral height (M-1)	(20.3)	22.0	23.6	26.2	(25)
Body dorsal height (M-2)	(26.5)	26.0	26.9	25.5	24.0
Body median height (M-3)	–	–	25.0	–	–
Body superior dorso-ventral diameter (M-4)	(31.6)	–	40.3	36.4	34.1
Body superior transverse diameter (M-7)	44.8	45.5	47.5	50.0	52.8
Body inferior dorso-ventral diameter (M-5)	–	39.7	37.2	(36.4)	(30)
Body inferior transverse diameter (M-6)	48.2	50.3	52.1	52.9	(50)
Body sagittal angle[10]	–15°	(–14°)	–10°	–6°	+8°

[1]From the mid-ventral surface of the body to the dorsal tip of the spinous process.
[2]Maximum distance between the lateral edges of the superior articular facets.
[3]Maximum distance between the medial edges of the superior articular facets.
[4]Average of the external and internal transverse articular diameters of the superior articular facets.
[5]Maximum distance between the lateral edges of the inferior articular facets.
[6]Maximum distance between the medial edges of the inferior articular facets.
[7]Average of the external and internal transverse articular diameters of the inferior articular facets.
[8]From the ventro-superior margin of the intersection of the laminae and the spinous process to the dorsal tip of the spinous process (not including the unfused tubercle).
[9]The angle between the central long axis of the spinous process and the horizontal plane of the superior surface of the body, taken in the median sagittal plane of the vertebra.
[10]Angle in the median sagittal plane between the tangents to the median sagittal surfaces of the superior and inferior vertebral disk surfaces (a positive angle has its apex dorsally and opens ventrally).
[11]Dorsal tubercle of spinous process unfused and missing.

The spinous process is of moderate length and is horizontally projecting from the corpus (Table 3). The dorsal supero-inferior body height is greater than that of the ventral surface, and the body is wide in transverse diameter relative to dorso-ventral diameter.

Lumbar vertebra 3 (fig. 6)

The third lumbar vertebra is complete except for the lateral portion of the right side transverse process. The tip of the spinous process is fused but the epiphyseal line is still open along its superior edge. The inferior and superior annular rings appear to be fully fused to the centrum, with the epiphyseal lines completely obliterated.

The spinous process is mildly angled inferiorly relative to the plane of the corpus (Table 3) and is of moderate length. The body is supero-inferiorly higher on its dorsal than ventral aspect. Both the body and spinal canals are wide transversely relative to their dorso-ventral dimensions.

Lumbar vertebra 4

The fourth lumbar vertebra is largely complete. It lacks only the spinous process and the right side transverse process. Slight erosion to the ventral surface of the body is evident. The superior surface of the body is covered by reconstructive material.

The ventral surface of the body is supero-inferiorly higher than the dorsal surface (Table 3). The corpus and spinal canal are transversely wide relative to their dorso-ventral diameters.

Lumbar vertebra 5

This vertebra is largely complete, lacking only the lateral ends of the transverse processes. Matrix is concreted to the left side transverse process, inferior articular facet and lamina. There is some erosion visible on the ventral surface of the body. The superior surface of the corpus is obscured by reconstructive material.

The spinous process is shorter than that of the third lumbar vertebra (Table 3) and is the most inferiorly directed of all the lumbar vertebrae. The ventral surface of the body is higher supero-inferiorly than the dorsal surface. The body and spinal canal are transversely wide relative to their dorso-ventral diameters.

Morphology

When articulated, the thoracic vertebrae show a normal kyphosis (Fig. 2). The sum of the ventral body heights is 196.5 mm (using the average of the ventral heights of the first and third vertebrae for the missing corpus of vertebra 2), considerably shorter than the mean value for recent European males reported by Boule and Vallois (1937) of 243.1 mm, and is closer to the mean value of 221.9 mm obtained for European females (standard deviations and sample sizes not given). This is a reflection of the shorter stature of the Gough's Cave 1 individual relative to recent European males (see Holliday & Churchill, this series). The total ventral body height of Cheddar Man is more similar to, yet still on the small side of, the male and female skeletons from Téviec (male skeletons 2 [217.5 mm] and 16 [231.0], female skeletons 1 [217.5] and 6 [223.5]: Boule & Vallois, 1937). This becomes more apparent when one looks at dorsal body heights, which are more reliable indicators of trunk height than are the ventral heights (which are frequently subject to anterior wedging: Stewart, 1966). Summary statistics for total thoracic column height (summed dorsal body heights for T1–T12) for comparative samples can be found in Table 4. The total thoracic height figure for Gough's Cave 1 and the majority of the fossil sample were predicted via least-squares regressions of total thoracic height on those elements preserved for a recent human series (n=45: Holliday, 1995). The standard error of the estimate for the measurements predicted by this method is very low (Holliday, 1995), providing a reasonable degree of confidence in the predicted values. In no case was a predicted thoracic height used if its standard error of the estimate was greater than 3% of the prediction itself.

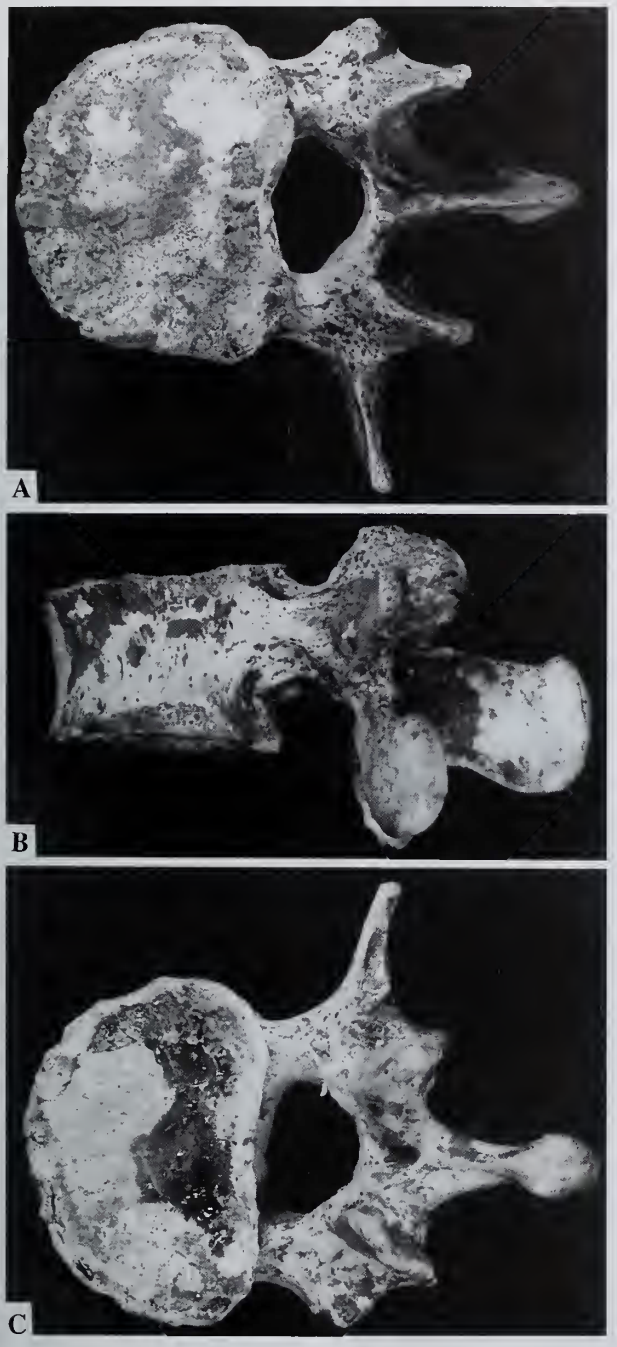

Fig. 6 Gough's Cave 1 third lumbar vertebra. **6a,** superior; **6b,** lateral; **6c,** inferior; × 0.9.

As is evident from Table 4, Gough's Cave 1 has a short thoracic column relative to most of the mean values for males in the comparative samples. The value for his thoracic height is less than that of all the male means, with the exception of the recent sub-Saharan Africans. His value falls within the low end of the male range for most of the samples. Interestingly, his thoracic height falls very close to the mean values of all of the European (Pleistocene, Holocene and recent) female samples. This of course reflects the overall short stature of the Gough's Cave 1 specimen.

Table 4 Summary statistics for thoracic column height (mm) in Recent and Late Pleistocene/Early Holocene samples (mean; SD; n).

	Total Thoracic Height	
	Male	Female
Gough's Cave 1	234.7	
Mesolithic Europeans	251.7; 20.4; 4	233.8; 5.7; 2
Late Upper Paleolithic Europeans	256.8; 18.1; 12	231.8; 10.1; 3
Recent Europeans	259.0; 12.9; 63	238.3; 12.6; 52
Recent North Africans	239.9; 15.8; 26	223.5; 8.4; 28
Recent Sub-Saharan Africans	229.6; 11.0; 9	219.7; 16.2; 15

When articulated, the lumbar vertebrae evince a normal lordosis (Fig. 5). The sum of the ventral body heights is more similar to those observed in the males from Téviec with five lumbar vertebrae (118.5 mm in Téviec 2, 116.0 in Téviec 4). The females from Téviec with five lumbar vertebrae have total ventral body heights that are slightly, but not substantially, shorter (110.0 mm in Téviec 1, 112.0 mm in Téviec 3). Three of the skeletons from Téviec have six lumbar vertebrae, without a reduction in the number of thoracic vertebrae, and thus have lumbar regions that are substantially longer supero-inferiorly (Téviec 16 [male], 155 mm; Téviec 6 [female] 148.5 mm: Boule & Vallois, 1937). As with the thoracic vertebral column, inclusion of the summed dorsal body heights of the lumbar vertebrae allows the comparison of Gough's Cave 1 to several Recent and fossil human samples. As for the thoracic column heights, lumbar column heights were predicted via least-squares regressions; none was used if its standard error of the estimate exceeded 3% of the predicted measurement. Table 5 shows that Cheddar Man has a shorter lumbar column than the male mean of all but one comparative sample (recent North Africans). To some extent, this is due to the marked posterior wedging exhibited in the specimen's L3–L5 vertebrae (see below). However, his relatively small size also plays a role; his lumbar column height falls squarely among the means for all the European female samples. Importantly, the male mean for the Mesolithic sample is high due to the inclusion of Téviec 16, who, as discussed above, has 6 lumbar vertebrae.

In recent Europeans, the ventral body height is typically greater than the dorsal body height in the fourth and fifth, and often in the third, lumbar vertebrae (Boule & Vallois, 1937). In the sample from Téviec, this pattern generally holds only for the fifth vertebra (Boule & Vallois, 1937). Gough's Cave 1 evinces the pattern seen in recent Europeans, with a greater supero-inferior dimension of the ventral body in the third, fourth and fifth lumbar vertebrae (Table 3). The lumbo-vertebral index (100 * [Σ dorsal body heights]/[Σ ventral body heights]) is 110.1 in Cheddar Man, higher than the mean value for the Téviec specimens but not outside their range (mean of six individuals = 103.6, range 96.3–110.1: Boule and Vallois, 1937). The position of the articular facets of the vertebrae indicate a lordotic curvature to the lumbar column (with perhaps greater lordosis created in the lower lumbars: Fig. 5), so there must have been considerable wedging of the intervening intervertebral disks.

Table 5 Summary statistics for lumbar column height (mm) in Recent and Late Pleistocene/Early Holocene samples (mean; SD; n).

	Total Lumbar Height	
	Male	Female
Gough's Cave 1	128.9	
Mesolithic Europeans	137.4; 13.5; 4	126.9; 8.4; 2
Late Upper Paleolithic Europeans	130.1; 8.6; 11	127.9; 2.5; 4
Recent Europeans	134.9; 8.0; 66	128.2; 7.4; 59
Recent North Africans	127.0; 10.5; 29	123.4; 7.3; 32
Recent Sub-Saharan Africans	131.5; 5.9; 11	122.7; 9.0; 15

The spinous processes of the thoracic and lumbar vertebrae are unremarkable and not particularly robust, similar to the condition observed in the Téviec skeletons (Boule and Vallois, 1937). The transverse processes of the lower thoracic vertebrae are, however, relatively large and robust. The insertion areas for the *levator costae* muscles and costotransverse ligaments tend to be well marked on the ribs (see below), suggesting some overall robusticity in the thorax of Cheddar Man (at least with respect to muscles and structures important in respiration). The inferior demi-facets for the rib heads on the centra are quite large in most of the thoracic vertebrae, and tend to form laterally-projecting tubercles with inferiorly directed articular surfaces. The flattening of the left side ventral bodies that usually occurs in thoracic vertebrae 5–8 (from pressure from the aorta) is only slightly apparent in Gough's Cave 1.

COSTAL REMAINS (FIG. 7)

Descriptions

RIB 2

The right second rib is preserved as a 78.8 mm-long fragment from the neck just proximal of the tubercle to the region of the proximal end of the *M. serratus anterior* tubercle (the proximal part of the tubercle is apparent). The left second rib is preserved as a 95.9 mm-long fragment from mid-neck to just distal of the *M. serratus anterior* tubercle, and the superior surface of the distal half of the fragment is covered with a thin layer of matrix (Fig. 7).

The right-side rib has a well developed crest for *M. scalenus posterior* and a distinct groove on the external edge of the inferior surface for the intercostal muscles and membranes. The *M. scalenus posterior* crest is not as strongly developed on the left-side rib (although the difference is slight), but the region just internal of the crest (on the superior surface) is more rugose. The *M. serratus anterior* crest on the left rib is very weakly developed. A piece of the superior surface of the shaft of this rib is missing in the region of the proximal tubercle, and the rest of the tubercle is covered by thin matrix, but it is clear nonetheless that the tubercle is not large. The left rib also displays a distinct groove on the external edge of the inferior surface for the intercostal muscles and membranes, but it is not as well defined as on the right side rib. The non-articular tubercles are relatively slight, with the one on the left rib being slightly larger. The articular facets (measuring 10.2 mm proximodistally (PD) by 6.1 mm supero-inferiorly (SI) on the right and 9.1 PD by 6.3 SI on the left) are dorsoinferiorly directed.

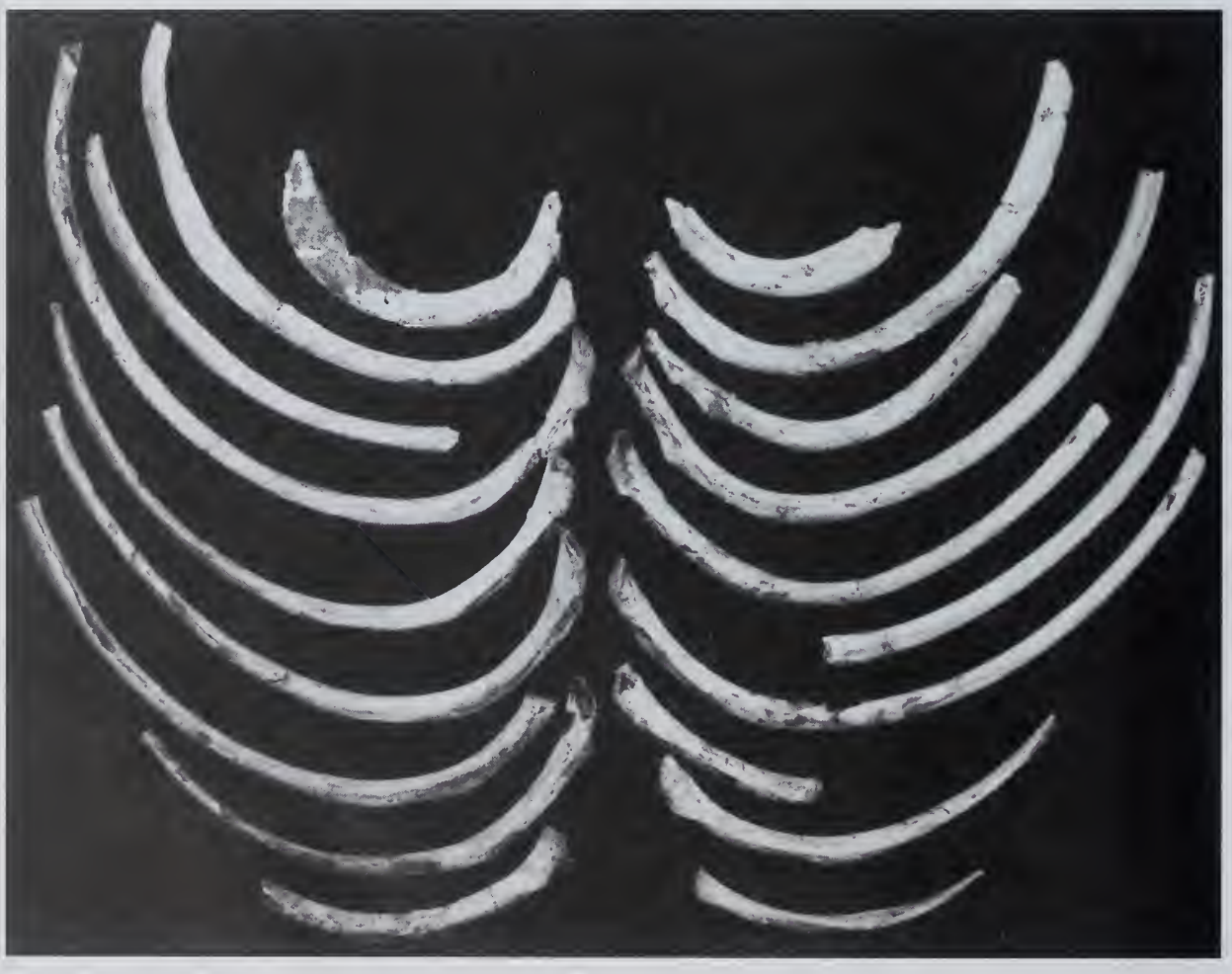

Fig. 7 Gough's Cave 1 ribs in superior view; × 0.43. The ribs are arranged in sequential order with the second ribs at the top and right-side ribs to the right of the photograph.

Table 6 Dimensions (mm) of ribs 2–4.

	R2	L2	R3	L3	R4
Neck length[1]	–	–	–	–	(27.9)[2]
Proximal thickness (M-2)	11.2	12.2	8.8	–	8.9
Proximal height (M-1)	7.3	7.1	8.4	–	9.3
Shaft thickness[3]	(11.7)[4]	(12.3)[4]	8.3	7.7	8.1
Shaft height[3]	(7.1)[4]	(7.3)[4]	11.7	10.1	7.7

[1]Distance from the middle of the head to the middle of the articular tubercle.
[2]Head unfused, measurement taken from middle of epiphyseal surface for head.
[3]Rib thickness (internal-external diameter, measured in the plane of rib curvature) and height (supero-inferior diameter, taken perpendicular to the plane of curvature of the rib) at the point where the *M. iliocostalis* line meets the inferior edge of the rib.
[4]Taken 1 cm distal of where proximal thickness and height were taken.

Rib 3

The right-side third rib is represented by a 154.7 mm-long fragment from mid-neck to just proximal of the anterior angle. The left third rib is preserved as a 171.7 mm-long fragment from the distal end of the posterior angle to just proximal of the sternal end.

The *M. iliocostalis* line[1] in the right rib is not pronounced (a feature of all of the Cheddar Man's ribs). A small portion of the *M. iliocostalis* line is preserved proximally in the left-side rib, and it looks to have been more strongly developed than in the right (however, the rib itself is somewhat slighter). The right rib shows a discernable attachment for *M. levator costae* and both ribs have a distinct sulcus on the superior edge of the rib in the vicinity of the posterior angle (ca. 30 mm long) for the intercostal muscles. There is no discernable subcostal groove on the right rib, and the left side shows a weak subcostal groove for only a few centimeters distal of the posterior angle. The left rib has a supero-inferior flare to the body about 45 mm proximal of the anterior angle, reflecting perhaps a healed fracture. The articular facet on the right side is dorsoinferiorly directed and measures 9.5 mm (proximodistally) by 7.8 mm (supero-inferiorly).

Rib 4

The right fourth rib is a 127.0 mm-long fragment preserved from the head to somewhere proximal of midshaft. The proximal end of the rib is intact. The left fourth rib is a 156.8 mm-long fragment of the rib body, from somewhere distal of the posterior angle to the region of the anterior angle.

On the right side, the surface of the head is rough and irregular, likely representing the subchondral surface of the unfused secondary centre of ossification for the head. There is a small and superiorly directed tubercle on the neck, and from this a crest runs distally along the superior margin of the bone past the non-articular tubercle, most likely representing the attachment of the superior costotransverse ligament. The *M. iliocostalis* line is not pronounced. The articular tubercle is large (9.0 mm proximodistally by 11.5 mm internal-external) and is primarily inferiorly directed. The subcostal groove is weakly developed on both ribs. In the right rib there is a strong bend at the posterior angle (the angle between the head-neck axis and the proximal costal body is approximately 90°).

Rib 5

The right fifth rib is preserved as a 190 mm-long fragment, intact from the head down to the anterior angle, and missing only a portion of the sternal end. The left rib is represented by a 210 mm-long fragment, also intact from the head down to the anterior angle and missing only a part of the sternal end.

The secondary centres of ossification for the heads are only partially fused (and portions are missing) on both sides. As in the right fourth rib, the fifth ribs present small superiorly directed tubercles on the neck that continue distally as crests running along the superior margins of the bones past the non-articular tubercles. These crests, most likely marking the sites of attachment of the superior costotransverse ligaments, are more strongly developed than that on the fourth rib. Both ribs also have a crest on the inferior edge of the neck running from the head to the proximoinferior edge of the articular facet. These crests may represent the attachments of expanded accessory ligaments from the heads and necks of the subjacent ribs (Williams & Warwick, 1980) or distal extensions of the radiate ligaments binding the heads to the adjacent vertebra. The nonarticular tubercles are bulbous and projecting, and the articular tubercles are inferodorsally directed (measuring 7.9 mm PD by 10.3 mm SI on the right, and 7.2 mm PD by 10.5 mm SI on the left). The *M. iliocostalis* lines are not very well developed and it is hard to make out where the lines cross the inferior border of the rib. The subcostal grooves are neither deep nor strongly developed but are clearly visible along most of the body. The angle between the head/neck axis and the axis of the body is about 117° on both sides.

Table 7 Dimensions (mm) of ribs 5–7.

	R5	L5	R6	L6	R7	L7
Rib length (M-4)	–	>200[1]	–	–	–	–
External arc (M-3)	–	>323[1]	–	–	–	–
Neck length[2]	(27.3)[3]	(28.5)[3]	(23.9)[3]	(25.3)[3]	–	(26.9)[3]
Proximal thickness (M-2)	9.2	8.3	8.0	8.6	–	8.9
Proximal height (M-1)	8.6	8.7	10.0	12.0	–	9.3
Shaft thickness[4]	9.3	9.6	8.6	8.7	9.7	9.3
Shaft height[4]	13.0	–	14.5	14.4	13.6	13.5
Chord[5]	–	(213)[1]	–	–	–	–
Subtense[6]	–	(77)[1]	–	–	–	–
Transverse width[7]	–	8.2	–	–	–	–

[1]Rib is missing a small portion of the sternal end.
[2]Distance from the middle of the head to the middle of the articular tubercle.
[3]Head unfused, measurement taken from middle of epiphyseal surface for head.
[4]Rib thickness (internal-external diameter, measured in the plane of rib curvature) and height (supero-inferior diameter, taken perpendicular to the plane of curvature of the rib) at the point where the *M. iliocostalis* line meets the inferior edge of the rib.
[5]Distance from the distal margin of the articular tubercle to the proximal extent of the sternal end, following McCown and Keith (1939: fig. 75).
[6]Maximum perpendicular distance from the chord to the external surface of the rib, following McCown and Keith (1939; fig. 75).
[7]Internal-external diameter of the rib body at the intersection of the subtense.

Rib 6

The right sixth rib is preserved as a 165.3 mm-long fragment, complete from the head to somewhere distal of midshaft. The left-side rib is a 185.1 mm-long fragment, complete from the head to the area of the anterior angle.

The centres of ossification of the heads are incompletely fused and portions of them are missing. The ribs of both sides have short necks with small tubercles on their superior surfaces for the superior costotransverse ligaments. The ribs lack the crests (distal of the tubercles) that are seen on the suprajacent ribs. The inferior edges of

[1]The iliocostal muscles are the lateral-most extensions of the *erector spinae* (*sacrospinalis*) muscle. The *M. iliocostalis lumborum* inserts on the inferior borders of the lower six or seven ribs, at the posterior angle (Williams & Warwick, 1980). *M. iliocostalis thoracis* arises from the superior borders of the angles of the lower six ribs and inserts on the superior margins of the upper six ribs. *M. iliocostalis cervicis* attaches to the superior borders of the third to sixth ribs. Thus various combinations of these muscles, as well as the thoracolumbar fascia, contribute to the formation of the *iliocostalis* lines on the external surface of the posterior angle of the ribs, and will be referred to throughout this description as the *iliocostalis* muscle.

the necks also lack the crests seen on the fifth ribs. The articular tubercles are primarily inferiorly directed and round in shape (right-side 9.7 mm PD by 9.5 mm internal-external (IE), left-side 9.4 mm PD by 9.5 mm IE). The nonarticular tubercles are almost absent, appearing as small dorsosuperior extensions of the articular facets. The *M. iliocostalis* lines are not rugose nor marked. The attachments for *M. levator costae* can be seen as crests on the superior edges of the ribs running distally from the level of the tubercles and blending into the *M. iliocostalis* lines. The subcostal grooves are clear and distinct. The head/neck axis to shaft axis angle is roughly 135° in both ribs.

Rib 7

The right seventh rib is preserved as a 181.1 mm-long fragment of the body, from somewhere distal of the posterior angle to just distal of the anterior angle. Judging from the size and curvature of the left side antimere, the proximal break occurred right at the distal end of the posterior angle. The left-side rib is represented by a 185.0 mm long-fragment, complete from the head to the region of the anterior angle.

The secondary centre of ossification for the head of the left rib is unfused and missing. The neck is short and has a tubercle and crest on its superior surface for the superior costotransverse ligament. The neck has a large foramen or pit (plugged with matrix) on its dorsal surface. The *M. levator costae* crest is pronounced. The articular facet is dorsoinferiorly directed and oval in shape (10.8 mm PD by 8.4 mm IE). The nonarticular tubercle is poorly defined but is larger than that of the 6th rib. The *M. iliocostalis* line is non-rugose and poorly defined. On both sides the proximal bodies are quite thick and form a 'roof' over the subcostal groove along the proximal shaft. The subcostal grooves are very clearly defined along the proximal portions of the shafts. In the left-side rib, the head/neck axis to body axis angle is strong (approximately 109°).

Rib 8

The right eighth rib is preserved as a 198 mm-long fragment, complete from the head to the area of the anterior angle. The left rib is preserved as a 190.3-mm long fragment of the body, retaining a small portion of the nonarticular tubercle proximally. Distally the left-side rib is broken somewhere proximal of the anterior angle.

On the right rib the head is unfused and missing. The neck is short and has a tubercle and crest on its superior surface for the superior costotransverse ligament. This crest is continuous with the insertion of *M. levator costae* and blends with the superior portion of the *M. iliocostalis* line distally. The same morphology can be seen in the left-side rib from the area of the *M. levator costae* insertion (the most proximally preserved portion of the shaft) down to the *M. iliocostalis* line. The inferior surface of the right-side neck also has a clearly defined crest, perhaps reflecting the attachment of an expanded accessory ligament from the head and neck of the subjacent rib (Williams & Warwick, 1980) or a distal extension of the radiate ligament. The neck has a foramen or pit on the dorsal surface just proximal to the articular facet. The articular facet is oval (11.6 mm PD by 9.3 mm IE) and is primarily inferiorly directed. The nonarticular tubercle is poorly defined and blends with the proximal end of the *M. iliocostalis* line. The *M. iliocostalis* lines are non-rugose and poorly defined on both ribs. Small, mildly rugose depressed areas can be seen on the superior margins of the shafts just distal to the *M. iliocostalis* lines, likely marking the proximal extent of the insertion of the intercostal muscles. The subcostal grooves are very clear along the proximal halves of the ribs. The head/neck axis to body axis angle of the right-side rib is 122°.

Table 8 Dimensions (mm) of ribs 8–11.

	R8	L8	R9	L9	R11	L11
Neck length[1]	(26.7)[2]	–	(22.5)[2]	(23.1)[2]	–	–
Proximal thickness (M-2)	10.2	9.3	8.4	8.2	–	–
Proximal height (M-1)	9.8	9.2	9.7	9.1	–	–
Shaft thickness[3]	–	10.6	–	7.9	6.9	6.3
Shaft height[3]	–	11.4	–	15.3	13.2	13.8

[1]Distance from the middle of the head to the middle of the articular tubercle.
[2]Head unfused, measurement taken from middle of epiphyseal surface for head.
[3]Rib thickness (internal-external diameter, measured in the plane of rib curvature) and height (supero-inferior diameter, taken perpendicular to the plane of curvature of the rib) at the point where the *M. iliocostalis* line meets the inferior edge of the rib.

Rib 9

The right ninth rib is a 79.6 mm-long fragment of the proximal end, complete from the head to the region of the posterior angle. The left rib is preserved as a 150.5 mm-long fragment, complete from the head to somewhere below midshaft.

The centres of ossification for the heads are unfused and missing. The necks are relatively short. In the right-side rib, a small tubercle is evident on the superior surface of the neck, perhaps reflecting an attachment for an accessory ligament that ran superiorly to the crest on the inferior surface of the neck of the right eighth rib. The crests for *M. levator costae* are clearly defined on both ribs. The articular facets are oval shaped (measuring 8.9 mm PD by 7.7 mm IE on the right, 8.9 mm PD by 8.0 mm IE on the left) and are inferodorsally directed. The nonarticular tubercles arise from the articular tubercles and are relatively small. The *M. iliocostalis* lines are not pronounced. The costal grooves are wide supero-inferiorly and shallow. The head/neck axis to shaft axis angle is 116° in both ribs.

Rib 11

The right eleventh rib is represented by a 130.5 mm-long fragment, complete from the head to somewhere near the anterior angle. The left-side rib is preserved as a 102.5 mm-long fragment, complete from the head to 37 mm below the posterior angle. The shaft of the left rib is eroded and damaged.

The heads are unfused and missing on both sides. The ribs present neither articular nor nonarticular tubercles, but crests for the costotransverse ligaments are visible on the superior margins of the proximal bodies. Narrow, oval insertion scars for the intercostal muscles are visible on both the inferior and superior edges at the posterior angle. The *M. iliocostalis* lines are indistinct, but bulging tubercles are visible at the posterior angle in each rib for the attachment of this muscle.

Rib 12

The right twelfth rib is complete, and has a total length of 96.6 mm. The area of the internal intercostal muscle attachment on the superior edge is eroded away, but otherwise the bone is well preserved.

The head appears to be unfused. The rib has a clear crest on the superior surface of the neck for the costotransverse ligament. There is also a sulcus on the inferior edge of the internal surface of the proximal shaft for *M. quadratus lumborum*. The diaphragm attachment is indistinct. There is a long (19 mm), narrow scar on the inferior edge of the distal shaft for *M. serratus posterior inferior*, and on the superior external surface some rugosity is visible that may represent the attachment site of *M. latissimus dorsi*. The right twelfth rib is 95.9 mm long (M-4: Martin, 1928) and has an external arc length (M-3: Martin, 1928) of 54 mm.

Unidentified shaft fragment

This is a 58.2 mm-long fragment of the distal end of a rib body, including the sternal end. The subcostal groove is not preserved, and thus the side cannot be determined. The fragment is somewhat damaged and has some areas of plaster reconstruction. The supero-

inferior height of the body is 14.4 mm. Based on the size and shape of the fragment, it appears to be part of an upper rib.

Morphology

The overall size (Tables 6–8), shape, robusticity and muscularity of the Gough's Cave 1 ribs fall within the range of variation of recent human samples. In terms of rib shaft height and thickness the Gough's Cave 1 ribs generally fall within one standard deviation of the mean values obtained in the comparative sample (Table 9). Rib shaft shape, as measured by the ratio of thickness to height, is also generally within one standard deviation of the EuroAmerican means. The notable exceptions concern the fourth and eighth ribs, both of which are markedly shorter in the supero-inferior dimension, resulting in shaft shape ratios that are elevated (indicating a 'rounder' shaft cross-section) relative to the comparative sample.

The *M. iliocostalis* lines are generally poorly marked in the entire series of ribs. Other muscle markings and ligamentous insertions tend to be more pronounced. Most of the ribs exhibit a distinct crest for *M. levator costae* and clear attachment areas for the superior costotransverse ligament. However, the insertions on the external surfaces of the rib necks for the costotransverse ligaments are not pronounced, and, with the exception of the fifth rib, the non-articular tubercles (upon which the lateral costotransverse ligaments attach) are slight. Evidence of expanded accessory or radiate ligaments can be seen in several of the ribs. The subcostal grooves tend to be weakly developed in the upper ribs of the series, but are distinct in the middle ribs. The insertion sites of the intercostal muscles are well defined in a number of the ribs. The insertion of *M. scalenus posterior* is evident in both second ribs, yet the *M. serratus anterior* tubercle is relatively slight in the left side rib (this region is not preserved in the right-side rib). In the preserved right twelfth rib, an obvious sulcus for *M. quadratus lumborum* can be seen, and the attachment areas of *M. serratus posterior inferior* and *M. latissimus dorsi* are clearly evident. The presence of crests for the *levator costae* muscles, along with the visible insertion sites of the intercostal muscles in some ribs and the development of the attachment areas of the ligaments that bind the ribs to vertebrae suggest a moderately high level of respiratory activity in this individual. However, this general robusticity does not extend to all of the muscles of the back and trunk that arise from or attach to the ribs.

Table 9 Rib shaft dimensions (mm) in Gough's Cave 1 and recent European-American males (mean, SD).

RIB		Gough's Cave 1	EuroAmerican Males (n = 20)
2	Thickness	(11.7)[1]	12.7 ± 1.1
	Height	(7.1)[1]	7.3 ± 0.8
	T/H ratio	1.65	1.73 ± 0.2
3	Thickness	8.3	7.8 ± 1.1
	Height	11.7	11.2 ± 1.7
	T/H ratio	0.71	0.71 ± 0.1
4	Thickness	8.1	8.6 ± 0.9
	Height	7.7	11.7 ± 1.9
	T/H ratio	1.05	0.74 ± 0.1
5	Thickness	9.3	9.0 ± 1.0
	Height	13.0	12.8 ± 1.6
	T/H ratio	0.72	0.71 ± 0.1
6	Thickness	8.6	9.2 ± 1.0
	Height	14.5	13.9 ± 1.5
	T/H ratio	0.59	0.67 ± 0.1
7	Thickness	9.7	9.0 ± 1.0
	Height	13.6	15.0 ± 1.9
	T/H ratio	0.71	0.61 ± 0.1
8[2]	Thickness	10.6	8.6 ± 0.8
	Height	11.4	15.5 ± 2.5
	T/H ratio	0.93	0.57 ± 0.1
9[2]	Thickness	7.9	8.0 ± 0.8
	Height	15.3	17.0 ± 2.8
	T/H ratio	0.52	0.48 ± 0.1
11	Thickness	6.9	6.1 ± 1.0
	Height	13.2	12.9 ± 1.6
	T/H ratio	0.52	0.48 ± 0.1

[1]Taken 1cm distal of location of proximal thickness and height measurements.
[2]Taken on left-side rib for Gough's Cave 1.

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